Io—the first satellite—and Jupiter in a period of 11h. 57m. 22·6s.

Following this discovery came the addition, to an already numerous family, of the ninth satellite of Saturn, which was found by Prof. W. H. Pickering. The search was commenced in 1888 with the 13-inch Boyden telescope of the Harvard College Observatory, but was not successful in bringing to light any previously unknown attendant on Saturn. On the installation of the new 24-inch Bruce telescope in the clear atmosphere of Arequipa the search, which was photographic throughout, was renewed, and on examining the plates taken on August 16, 17, and 18, 1898, Prof. Pickering was rewarded by the appearance of a short trail which apparently partook of the planet's motion among the stars, and was, therefore, to be considered as part of its system. The story of the subsequent doubts and difficulties has been too recently told (Harvard College *Annals*, No. 3, vol. liii.) to need re-telling here, but it may be recalled to mind that the subsequent observations showed that the satellite revolves in an orbit which is far more eccentric than that of any other satellite, or of any major planet, in the solar system, and that its motion in that orbit is opposite in direction to the orbital motions of the remaining eight of Saturn's moons. Like the fifth satellite of Jupiter, this object can only be observed visually with the largest telescopes and under the best conditions. As a matter of fact, it was not *seen* until its position was accurately known, and even then Profs. Barnard and H. H. Turner, using the 40-inch refractor at Yerkes Observatory, in August last, could not feel certain that they had really observed the object which had up to that time remained invisible to human eyes.

Whilst our knowledge of the most recently discovered satellite is as yet very scanty, Prof. Perrine's message tells us that on January 4 its position angle was 269°, and the daily rate of its apparent approach towards Jupiter was 45″, *i.e.* about 100,000 miles.

The magnitude, 14, ascribed to it is one magnitude fainter than that of Barnard's fifth satellite, and this primarily suggests that the diameter may be less than that of the fifth, although a smaller reflecting power, or "albedo," may account for the relative faintness. Its distance from Jupiter on January 4 would probably be about 6 million miles. The statement that the motion was "retrograde" refers, of course, to the apparent motion in the sky, and must not be confounded with a retrograde orbital motion similar to that followed by Phœbe, Saturn's ninth satellite.

W. E. R.

ATMOSPHERIC AND OCEANIC CARBON DIOXIDE.

THE carbonic acid of sea-water is usually supposed to be present in combination with certain bases, which constitute the *alkalinity* of the water, partly in the form of normal carbonate and partly in the form of bicarbonate, the total amount present being insufficient to convert the whole of the base into the bicarbonate. Thus the water of the North Atlantic has been found to contain 49 c.c. of carbonic acid gas per litre, whilst 54 c.c. would be required to convert the base completely into bicarbonate. That this view is not quite correct has been shown by Dr. A. Krogh, of Copenhagen, in a series of investigations on the carbon dioxide of the air and ocean.[1]

The reaction between carbonic acid and a normal carbonate to form a bicarbonate is, like so many chemical reactions, reversible, and equilibrium is established while a certain amount of the carbonic acid is still free. This free carbonic acid exerts a definite gaseous pressure, which varies with the total amount of carbon dioxide present and with the alkalinity of the water. This pressure can very readily be determined by simply shaking the water with a small volume of air and then ascertaining by direct analysis the pressure of the carbon dioxide in this air, which is, of course, equal to the pressure of that in the water, since the two have been brought into equilibrium by the shaking. This process gives excellent results both with fresh- and sea-water, and can be carried out very rapidly by the aid of the apparatus of Haldane or Petterson and Sonden for the estimation of small quantities of carbon dioxide. As the result of a careful study of the behaviour of sea-water in this respect, it appears that a comparatively large amount of carbon dioxide may be absorbed, whilst the corresponding pressure only undergoes a very small absolute change, provided that the alkalinity remains constant. A water, for example, which has the alkalinity 23, and contains 36·7 c.c. of carbon dioxide per litre, is capable of absorbing 4·3 c.c. of the gas per litre, whilst the pressure, measured as described above, only rises from 0·015 per cent. to 0·0295 per cent. of an atmosphere. This means that the air shaken up with the original water would be found to contain 1·5 parts of carbon dioxide per 10,000, whilst after the further absorption the air similarly treated would contain 2·95 parts per 10,000.

Owing to this pressure of carbon dioxide constant interchange takes place between every water surface, whether of sea-water or of fresh-water, and the air above it, resulting in evolution from the water or absorption by it according as the pressure of carbon dioxide in the water or the air is the greater. The effect of this is that the ocean acts as a regulator on the amount of carbon dioxide in the air, tending to compensate for any deviation from the normal proportion. The pressure of carbon dioxide in the air is at present about 0·03 per cent. of an atmosphere (3 volumes per 10,000), the absolute amount in the whole atmosphere being calculated as $2{\cdot}4\times10^{12}$ tons, whilst the quantity contained in the entire mass of the sea may be taken as twenty-seven times as great as this.

In order to increase the proportion of the atmospheric carbon dioxide to 0·04 per cent. it would be necessary, of course, in the first place to add one-third of the amount already present. The pressure thus attained would, however, be gradually decreased by absorption by the sea, and it follows from the author's experiments that in order to bring the ocean into equilibrium with the altered atmosphere a further addition of twice the amount originally present would be required, a total change involving the production of $5{\cdot}6\times10^{12}$ tons of carbon dioxide! A calculation of this kind goes far to explain the constancy of composition of the atmosphere, which at first sight appears so remarkable, and to indicate the enormous changes required to produce any considerable variation in it.

The interchange of carbon dioxide between sea and air, moreover, is by no means a slow process, but takes place with remarkable rapidity. Thus a pressure difference between sea and air of only 0·001 of an atmosphere, *i.e.* the presence in the air of an additional 0·1 part of carbon dioxide per 10,000, leads to the absorption of 0·525 c.c. of this gas per square centimetre of ocean surface per year, or a total annual absorption of $3{\cdot}85\times10^{9}$ tons.

The author considers from this point of view the effect on the composition of the atmosphere of the combustion of coal, which annually throws into the air about one-thousandth of the carbon dioxide already present in it, so that, apart from any regulating action of the sea, in a thousand years—if the coal lasted—the percentage proportion would be doubled, rising from 3 to 6 volumes per 10,000, and rendering the air almost unfit for continued respiration. Before the proportion rose to 3·1 volumes per 10,000, however, the sea would be able to absorb the gas as fast as it was produced, and, owing to the large volume required to bring the ocean water into equilibrium with the air, it is probable that at the expiration of the thousand years the proportion of carbon dioxide in the air would not be more than 3·5 volumes per 10,000.

Many other interesting questions of great importance in the economy of nature are capable of being attacked from this point of view and subjected to experimental investigation. Such are the rate of deposition of calcium carbonate from hard waters, the rate of solution of limestone and chalk in natural waters, the absorption of carbon dioxide by rocks and soils, &c.

On the great question as to whether the production of carbon dioxide is on the whole greater or less than its decomposition nothing certain is known. Indications are not wanting, however, that this constituent of the atmosphere is increasing in quantity. The chief evidence to this effect is derived from the fact that over the sea the pressure of

1 "Meddelelser om Gronland," vol. xxvi. pp. 333, 409.

this gas is distinctly lower than over the land. This would appear to be most easily accounted for on the assumption that the pressure of carbon dioxide in the sea is constantly lower than that in the air, and that, therefore, the air must be steadily deriving supplies of the gas from some source, by means of which this difference of pressure is maintained.

A. HARDEN.

CONFERENCE OF PUBLIC SCHOOL SCIENCE MASTERS.

THE annual meeting of the Public School Science Masters' Association was held for the second time at Westminster School on January 14, by kind permission of Dr. Gow, who had undertaken the duties of president and occupied the chair. A letter was read by the honorary secretary, Mr. W. A. Shenstone, from Sir Michael Foster explaining why he had not been able to act as president. The meeting then occupied itself with business matters, and Sir Oliver Lodge was unanimously elected president for the ensuing year.

In the short address with which Dr. Gow opened the conference, he expressed the opinion that every boy should be taught natural science, and this pronouncement, coming as it does from a classical headmaster, is of very great importance at the present moment, as Prof. Armstrong was not slow to point out. It was no doubt elicited by the subject of the first paper, namely, the importance of including both Latin and science in a scheme of general education. This was read by Mr. Douglas Berridge, of Malvern College. In the paper the necessity of a general education was discussed, and the report of the committee upon the education of army officers was taken as a guide. In this it is laid down that English, mathematics, one modern language, Latin, and science are essential to a sound general education; but what is very strange, the framers of the report proceed to propose that all future officers of our Army should be debarred from obtaining what was considered necessary by the proposal that Latin and science should be optional and alternative subjects. In addition to the injury which a one-sided education inflicts upon the individual, Mr. Berridge pointed out a greater and more far-reaching danger to our nation as a whole. He urged that the present trend of education, as represented by London University (in its matriculation and school leaving examination), by Oxford and Cambridge (in their school leaving examinations), and by the Civil Service Commissioners and the Army entrance examinations, is sharply to divide Englishmen into two classes, the one trained on literary lines, leavened only by a modicum of mathematics, the other on scientific lines, leavened only by a smattering of French. Could it be, Mr. Berridge asked, to the advantage of any nation that its future rulers and organisers should thus be grouped into two opposing camps, of which, while they mutually despise one another, neither is able to understand the very method of reasoning adopted by the other? Mr. Berridge was able to support his contention by figures, for on application to all our public schools he had found that for the Army and matriculation examinations 45·6 per cent. of the boys now learn Latin and 54·4 per cent. learn science.

The discussion showed that while the need of a literary as well as a scientific training was thoroughly recognised, many speakers did not agree with Mr. Berridge that Latin was the best means of acquiring the former. It is true that Father Cortie (Stonyhurst) found that the best classical boys were most successful in science, but Prof. Armstrong said that no honest attempt had ever been made in this country to afford a literary training through any other language, and though Latin had proved very efficient in a few instances, in the vast majority of cases it was not. He maintained, also, that Latin translation did not give style. Finally, Prof. Armstrong characterised the making of science alternative to Latin in Army examinations as illogical and preposterous. Dr. Gow said that he never regarded Latin as a literary training, but as a scientific one, and referred to his opening remarks, in which he had characterised the words as typical and exceptional genera and species, and parsing as scientific classification.

The paper dealing with recent proposals for school leaving certificates, by Mr. C. I. Gardiner, of Cheltenham, dealt with what has been done on the Continent, and afterwards with the regulations at present suggested to the Board of Education by its consultative committee. The paper welcomed, as did many of the speakers afterwards, what is not very happily expressed as State interference. Many of the Board of Education's proposals were characterised by Mr. Gardiner as too vague, upon very good grounds. In the discussion, surprise was expressed that Mr. Gardiner had not mentioned what has been done recently in Ireland. It was recommended, also, that the Board of Education should get to know the schools before it suggested too much, and that its interference should be taken in small doses. Mr. W. A. Shenstone fancied he saw the edge of red tape in some of the proposals, while Father Cortie thought there was a danger that education might become stereotyped, so that special traits of certain schools would not be given free play. He hoped that inspectors with fads or insufficient knowledge would not interfere as they had done in elementary schools, and would not say, for instance, "your 'labs' are not so good as those in the primary schools (which are built with the ratepayers' money), you must erect new ones."

The third paper dealt with the use and misuse of terms in science teaching. It was contributed by Mr. T. L. Humberstone, of Toynbee Hall, who took exception to the loose way in which words, law, theory, hypothesis, and so on were used. He pointed out what the real meanings of the words were, and objected strongly to the idea that the experiments in practical mathematics "proved" the laws that they were intended to illustrate. Prof. Tilden agreed with Mr. Humberstone in regard to the misuse of terms, and said that professional scientific men were just as much to blame as schoolmasters. He thought that if boys were taught a little logic before they left school many mistakes would be prevented. He was amazed at the statement incidentally made by Mr. Humberstone as to there being too much laboratory work done in schools, and he pointed out that every discovery of the organic chemists was additional evidence in favour of the atomic theory which Mr. Humberstone thought was tottering. Mr. Fletcher, of the Board of Education, said that there was a widespread misapprehension as to the place of practical work in geometry. It was not possible to prove anything by the experiments used, but it was most important to get approximations which could be idealised into conceptions. They were necessary to create a state of mind and to commend postulates to common sense. Mr. Sanderson thought that some of the practical work set to boys was superfluous, and might well be replaced by good experiments shown by the master. Mr. Humberstone, in answer to a question from Mr. Shenstone, said that he thought ten or twelve hours a week was longer than was required for laboratory work, and he further said, with regard to superfluous work, that when a boy had learned how to obtain one gas properly it was not necessary for him to produce all the others.

The last paper was by Mr. F. B. Stead, of Clifton, and was on the possibility of teaching scientific method to boys whose education is almost entirely literary, and who have no time for a regular course in chemistry and physics. It was suggested that older boys in the Vth form should be given some definite piece of work to be carried out in detail, in order that they might understand (1) the method of experiment and observation by which facts are ascertained; (2) the process of reasoning from particular instances to general laws; and (3) the use of explanatory theories and their verification.

Prof. Armstrong considered the paper to be one of very great value, and suggested that the term "experimental" should be used instead of "scientific," bearing in mind what Dr. Gow had said in connection with Latin as scientific training. He also asked what place there would be in the near future for boys who only had had a literary education.

WILFRED MARK WEBB.